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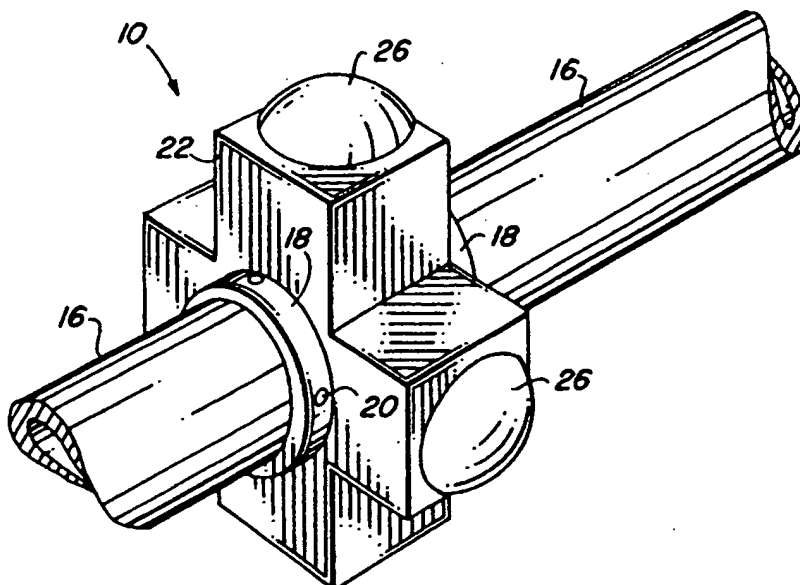
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| (21) International Application Number: PCT/US94/02974 (22) International Filing Date: 18 March 1994 (18.03.94) (30) Priority Data: 08/044,320 7 April 1993 (07.04.93) US (71) Applicant: MARATHON OIL COMPANY [US/US]; Patent Department, 539 South Main Street, Findlay, OH 45840 (US). (72) Inventor: STOLTZ, Ronald, P.; 3601 Crestmont Drive, Midland, TX 79707 (US). (74) Agents: HUMMEL, Jack, L. et al.; Marathon Oil Company, P.O. Box 269, Littleton, CO 80160-0269 (US). | | (81) Designated States: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TT, UA, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |

(54) Title: **HIGH ANGLE AND HORIZONTAL WELLBORE CENTRALIZER AND METHOD OF USE**



(57) Abstract

A method and apparatus for running in a tubing string through a high angle or horizontal wellbore without damage to equipment on the tubing string. Centralizers are mounted on the tubing string at spaced intervals on either side of the equipment. The centralizers include spherical rollers which contact the wellbore casing and which are mounted so as to have little or no radially inward movement.

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HIGH ANGLE AND HORIZONTAL WELLBORE
CENTRALIZER AND METHOD OF USE

Field of the Invention

This invention relates to completion activities
5 conducted in high angle and horizontal wellbores. More
particularly, it relates to a method and means for
facilitating the movement of tubing strings through such
wellbores and for protecting equipment carried by the
tubing strings against damage.

10 Background of the Invention

Due to developing technology, horizontal wells are
now being used both as producing wells and injection
wells in the petroleum industry. Although selective
perforation and stimulation activities are now able to be
15 carried out in cased horizontal wells as well as in
vertical wells, difficulties have been encountered in
moving tubing strings and related equipment through the
high angle and horizontal sections of the wells. As they
traverse these sections, the tubing string and the
20 completion equipment carried by the tubing string tend to
slide along the bottom of the wellbore. This causes the
operators to have a loss of "feel" to the tubing and
tools, which is detrimental to accurately moving and
positioning the tools in the desired area. It can also
25 result in damage to the tubing string or equipment,
requiring the tubing string to be withdrawn and the
damaged portions of the tubing and equipment replaced.

In addition, difficulties have been encountered in
properly placing and preventing damage to equipment used
30 in multiple zone completion activities in horizontal
injection wells.

It would be highly desirable to be able to carry out
completion activities in horizontal wells without
encountering problems caused by the traversing of tubing
35 strings through high angle and horizontal sections of the
wellbores.

Brief Summary of the Invention

In carrying out the invention, equipment used in
completion activities in a cased high angle or horizontal

wellbore is attached to a tubing string. The equipment extends radially outwardly from the tubing string a distance less than the distance from the tubing string to the wellbore casing so that there is clearance between the equipment and the casing. Centralizers are mounted on the tubing string at locations upstream and downstream of the equipment. In some instances this may result in centralizers being provided on either side of a single piece of equipment. In others, depending on the completion procedures being carried out, centralizers will be provided on either side of a group of separate pieces or units of equipment.

The centralizers include spherical rollers which extend radially outwardly from the tubing string a distance substantially equal to the distance from the tubing string to the wellbore casing. When the tubing string is run into a cased high angle or horizontal wellbore, the spherical rollers of the centralizers contact the casing, thereby permitting the tubing string to have both axial and rotational components of movement through the casing. This is especially beneficial in cases where certain equipment requires the tubing string to be rotated, as in the case of a packer that requires rotation of the tubing string in order to be set. This arrangement of centralizers and equipment also protects the equipment against damage resulting from contact between the equipment and the casing during both running in and withdrawal of the tubing string from the casing.

Each spherical roller of the centralizer is mounted for rotation in a spherically shaped recess in a support body secured to the tubing string. The rollers are mounted in such a manner that they have substantially no radial movement capability. This gives a positive stand-off to the equipment or tools mounted on the tubing string, thereby preventing them from becoming damaged.

The above and other aspects and benefits of the invention will readily be apparent from the more detailed description of the preferred embodiment which follows.

Brief Description of the Drawing

FIG. 1 is a pictorial view of the centralizer of the invention, shown mounted on a tubing string;

FIG. 2 is a side elevation of a horizontal cased wellbore partially broken away to reveal a tubing string having a centralizer mounted thereon;

FIG. 3 is a transverse sectional view taken on line 3-3 of FIG. 2;

FIG. 4 is an enlarged partial transverse sectional view of a recessed portion of the centralizer body, showing a spherical roller mounted therein;

FIG. 5 is an enlarged partial transverse sectional view similar to that of FIG. 4, but showing a different mounting means for the spherical roller;

FIG. 6 is a longitudinal sectional view of a high angle section of a cased wellbore in which a tubing string, having centralizers mounted thereon, is positioned; and

FIG. 7 is a longitudinal sectional view similar to that of FIG. 6, but showing a tubing string and centralizers positioned in a horizontal section of a cased wellbore.

Detailed Description of the Preferred Embodiment

Referring to FIGS. 1, 2, 3 and 4, the centralizer of the invention comprises a body 12 containing a centrally located bore 14 of a size to receive the tubing string 16. The centralizer may be mounted on the tubing string by sliding it onto a tubing string section and then anchoring it against sliding movement in either direction by means of stop rings 18 attached to the tubing string by lock screws 20. Other alternative ways of securing the centralizer body to a tubing string section can be used as desired, such as by providing screw threads on the bore 14 and threading the centralizer onto the end portion of a tubing string section.

The centralizer body is shown as having four outwardly extending support arms 22, each of which contains a bowl-shaped recess 24 for receiving a spherical

roller element 26. The centralizer support arms 22 extend radially outwardly of the tubing string, terminating short of the wellbore casing 28. The recesses 24 and spherical rollers 26 are dimensioned to allow the rollers to extend
5 radially outwardly to a point at which the rollers engage the inner surface of the casing.

The spherical rollers may be mounted in any convenient manner which allows them to rotate in any direction. For example, as shown in FIG. 4 the roller is
10 mounted in a bowl-shaped spherical recess 24 which has a radius of substantially the same length as the radius of the spherical roller 24. A retaining plate 29 attached to the outer surface of the support arm 22 has an inner surface which is contoured as a continuation of the recess
15 24 so as in effect to form part of the recess. The combined recess formed by the recess 24 and the inner surface of the retaining plate 29 receives a major portion of the spherical roller 26, thereby preventing the roller from escaping the recess.

20 The surface of the centralizer body forming the recess 24 in the arrangement shown in FIG. 4 is comprised of a polished bore, and the inner surface of the retaining plate 29 is also a polished surface. This reduces the friction between the recess and the roller, facilitating
25 movement of the centralizer along the surface of a wellbore casing. Preferably, grease fittings 30 are provided to allow grease or other friction reducing material to be introduced into the recess. A continuous seal 32 is provided in the retaining plate 29 to prevent
30 entry of foreign material into the recess.

Another roller mounting arrangement is shown in FIG. 5, wherein the recess 34 is larger than the recess 24 of the FIG. 4 arrangement and wherein ball bearings 36 are provided in rings 38 that fit within the recess 34. The
35 spherical rollers 26 are supported on the ball bearings 36, which further facilitates easy rotation of the rollers. A retaining plate 29 similar to the plate shown in FIG. 4 may also be provided.

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It will be noted that in both roller mounting arrangements the spherical rollers are supported on unyielding surfaces. This is made possible by the fact that the rollers extend out from the tubing string substantially the same distance that the tubing string is spaced from the wellbore casing, thereby providing for the rollers to contact the casing. If it is desired to employ a centralizer on a tubing string to be run in a wellbore of a different diameter, centralizers having dimensions to fit that particular size wellbore would be employed. By mounting the rollers on unyielding surfaces, as opposed to being mounted in a yielding manner, such as, for example, on a spring biased surface, the centralizers prevent relative transverse or radial movement between a wellbore casing and the tools mounted on a tubing string, thereby preventing damage to the tools and enabling the tubing string to be moved smoothly through the casing.

Referring now to FIG. 6, a tubing string 16 is shown in the process of traversing a high angle section of wellbore casing 28. For the purpose of illustration, tools or other equipment are shown mounted on the tubing string at spaced locations, with a centralizer 10 positioned both upstream and downstream of the equipment. It can be seen that the tools or equipment, which extend out from the tubing string a lesser distance than the centralizers, will not contact the wellbore casing at the critical curved transition areas between wellbore sections of different angles since the centralizers maintain the tubing string on a path which substantially coincides with the axis of the wellbore. Although only a single tool has been shown between centralizers, it will be understood that tools may be grouped together between centralizers as long as the centralizers are spaced close enough to each other to prevent the tools from contacting the casing at the curved portions of the wellbore.

A tubing string is shown in FIG. 7 in a horizontal section of wellbore casing 28 in connection with a multiple zone injection well completion process. In this

-6-

process, to ensure injection into each interval, a multiple packer assembly and regulator set-up are utilized. For such an operation the casing is provided with perforations 42, and snap set packers 44 and side-pocket flow regulators 46 are mounted on the tubing string 16. Centralizers 10 are positioned on the tubing string downstream and upstream from the packers and flow regulators to prevent the tubing string from sagging down and causing the packers and flow regulators to slide along the casing. Not only is the tubing string moved through the wellbore casing more easily as a result, giving the operator more feel for the assembly as it traverses the horizontal section, but the tubing string is able to easily rotate upon demand in order to set the packers 44. While the packers and flow regulators are one example of units of equipment that are normally clustered together between centralizers, obviously other types of equipment may beneficially be grouped together between centralizers to benefit the operation.

The centralizer has been illustrated as having four spherical rollers which are equally spaced about the periphery of the centralizer body. This preferred arrangement provides support at opposite points on the casing to maintain the tubing string at the axis of the casing. It also provides a sufficient number of spherical rollers to enable easy movement through the casing as well as allowing the tubing string to have rotational movement as well. Thus, required rotational movements of the tubing string, such as those necessary for the setting of packers, as well as rotational components of generally axial tubing string movement caused by turns and curvatures in the casing, are greatly facilitated. As few as two equally spaced spherical rollers may be provided, as long as such an arrangement makes the desired facility of movement of the tubing string possible. Conversely, as many equally spaced rollers as may conveniently be mounted on a centralizer can be employed to provide the maximum amount of support and the maximum ease of movement of a

tubing string through the wellbore casing.

It can now be appreciated that the present invention provides for a very economical means of facilitating completion operations in high angle and horizontal wells while at the same time preventing damage to equipment carried by a tubing string. The savings resulting from not having to replace damaged equipment and not having to repeat failed operations can be quite significant. The centralizer units themselves are simple in design and economical to fabricate, enabling different size centralizers to be kept on hand for use in various size wellbores.

It will now also be apparent that the invention is not necessarily limited to all the specific details described in connection with the preferred embodiment, but that changes to certain features of the preferred embodiment which do not alter the overall basic function and concept of the invention may be made without departing from the spirit and scope of the invention, as defined in the appended claims.

WHAT IS CLAIMED IS:

1 1. A method of running in a tubing string for
2 carrying out completion activities in a cased high angle
3 or horizontal wellbore, comprising:

4 attaching equipment to the tubing string for use in
5 the wellbore, the equipment extending outwardly from the
6 tubing string a distance less than the distance from the
7 tubing string to the wellbore casing;

8 mounting centralizers on the tubing string at
9 locations upstream and downstream of the equipment, the
10 centralizers including spherical rollers which extend
11 outwardly from the tubing string a distance substantially
12 equal to the distance from the tubing string to the
13 wellbore casing; and

14 running the tubing string into the cased high angle
15 or horizontal wellbore, the spherical rollers of the
16 centralizers contacting the casing of the wellbore,
17 thereby permitting the tubing string to have both axial
18 and rotational components of movement through the casing
19 and preventing the equipment from contacting the casing
20 during travel therethrough.

1 2. A method of running in a tubing string according
2 to claim 1, including the additional steps of using the
3 equipment in well completion activities and withdrawing
4 the tubing string from the casing after carrying out the
5 well completion activities.

1 3. A method of running in a tubing string according
2 to claim 1, wherein the equipment comprises a plurality of
3 separate spaced units of equipment and wherein
4 centralizers are mounted on the tubing string upstream and
5 downstream of each such unit.

1 4. A method of running in a tubing string according
2 to claim 1, wherein the equipment comprises a plurality of
3 spaced groups of units of equipment and wherein
4 centralizers are mounted on the tubing string upstream and
5 downstream of each group of units.

1 5. A method of running in a tubing string according
2 to claim 1, wherein the equipment includes a packer

3 requiring rotation of the tubing string in order to be
4 set, the method including the step of rotating the tubing
5 string to set the packer.

1 6. A method of running in a tubing string according
2 to claim 1, wherein each centralizer comprises a support
3 body mounted on the tubing string, the support body having
4 a plurality of regularly spaced recesses in the periphery
5 thereof, each recess having a spherical roller mounted for
6 rotation therein so as to be substantially incapable of
7 radially inward movement.

1 7. A method of running in a tubing string according
2 to claim 6, wherein the centralizer support body includes
3 at least four regularly spaced recesses having spherical
4 rollers mounted therein.

1 8. A method of running in a tubing string according
2 to claim 6, wherein each recess comprises a polished
3 spherically contoured bore for receiving a major portion
4 of the spherical roller, the bore including means for
5 decreasing the friction between the spherical roller and
6 the bore.

1 9. Apparatus for running in a tubing string for
2 carrying out completion activities in a cased high angle
3 or horizontal wellbore of predetermined diameter,
4 comprising:

5 a tubing string having a known diameter for use in
6 the wellbore;

7 equipment mounted on the tubing string and extending
8 outwardly therefrom a distance less than the difference
9 between the radii of the tubing string and the wellbore
10 casing;

11 centralizers mounted on the tubing string at
12 locations upstream and downstream of the equipment; and

13 the centralizers including spherical rollers which
14 extend outwardly from the tubing string a distance
15 substantially equal to the difference between the radii of
16 the tubing string and the wellbore casing;

17 the spherical rollers permitting the tubing string to
18 have both axial and rotational components of movement when

19 being moved through the casing and preventing the
20 equipment mounted on the tubing string from contacting the
21 casing during travel therethrough.

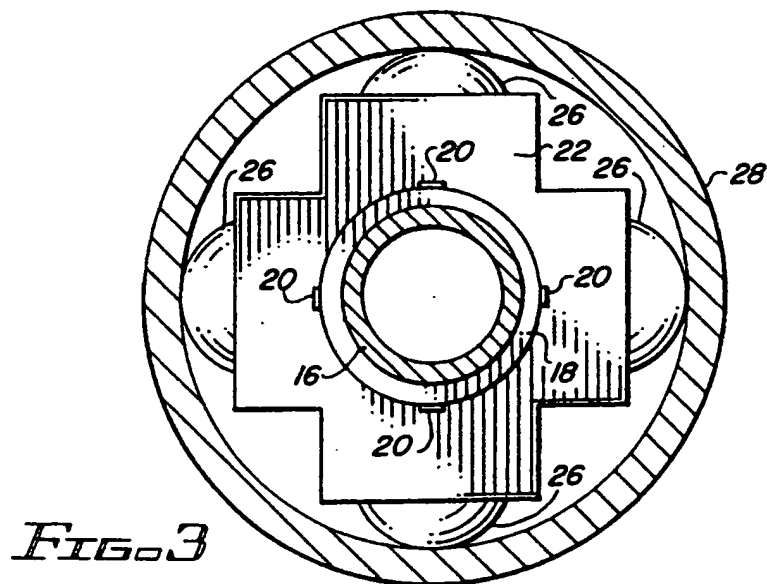
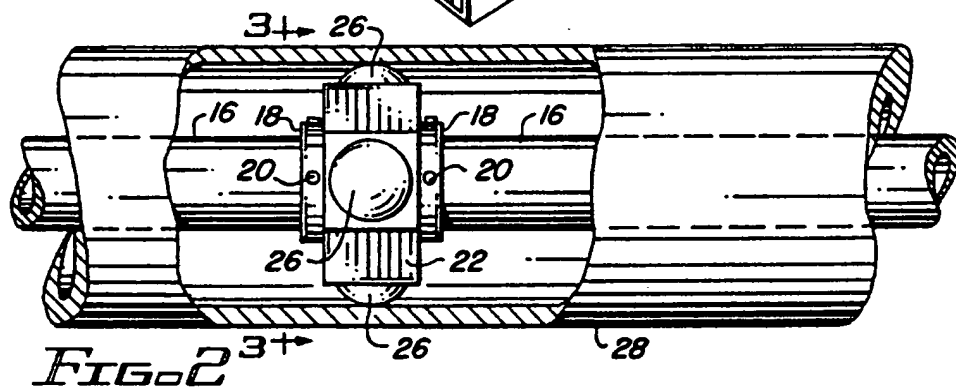
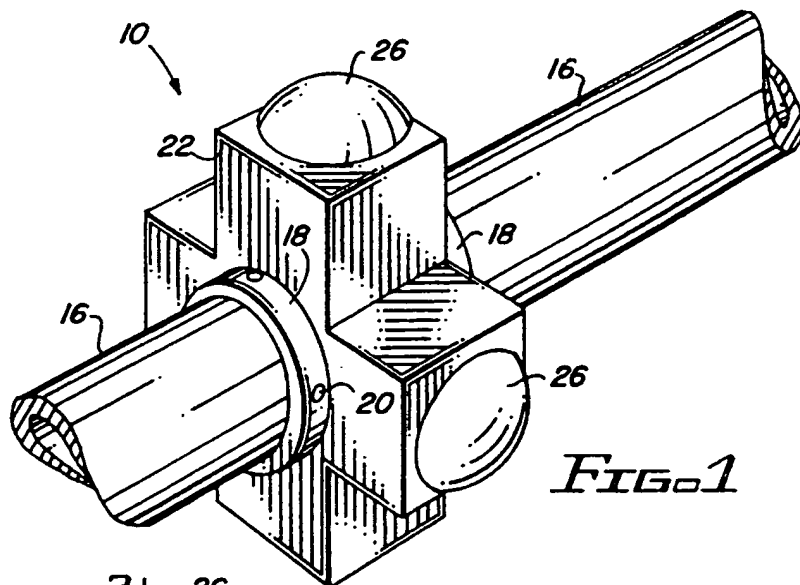
1 10. Apparatus for running in a tubing string
2 according to claim 9, wherein each centralizer comprises
3 a support body mounted on the tubing string, the support
4 body having a plurality of regularly spaced recesses in
5 the periphery thereof, each recess having a spherical
6 roller mounted for rotation therein so as to be
7 substantially incapable of radially inward movement.

1 11. Apparatus for running in a tubing string
2 according to claim 10, wherein the centralizer support
3 body includes at least four regularly spaced recesses.

1 12. Apparatus for running in a tubing string
2 according to claim 10, wherein each recess comprises a
3 polished spherically contoured bore for receiving a major
4 portion of the spherical roller, the bore including
5 friction reducing material therein in contact with the
6 roller.

1 13. All inventions substantially as shown and
2 described herein.

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2 / 2

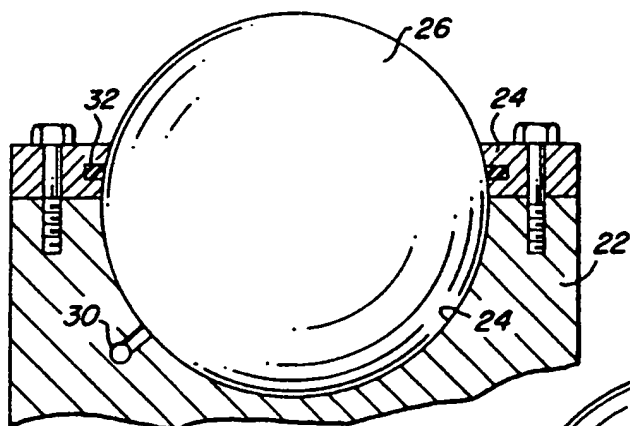


FIG. 4

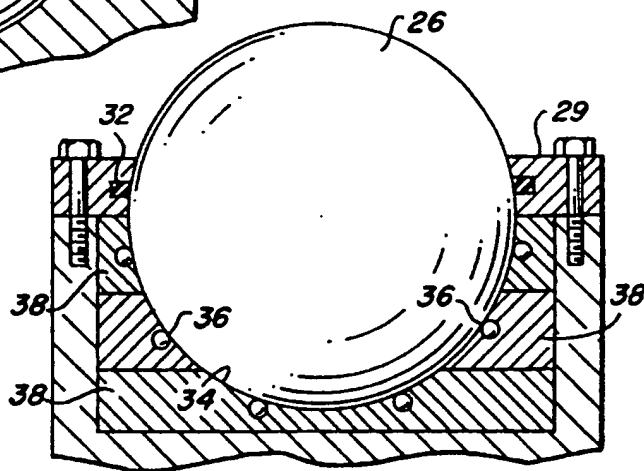


FIG. 5

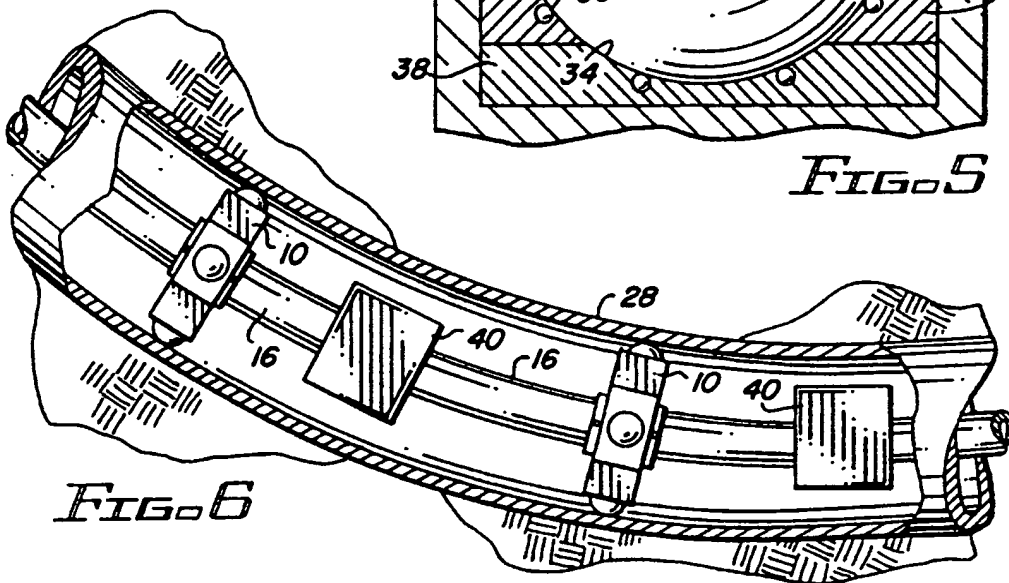


FIG. 6

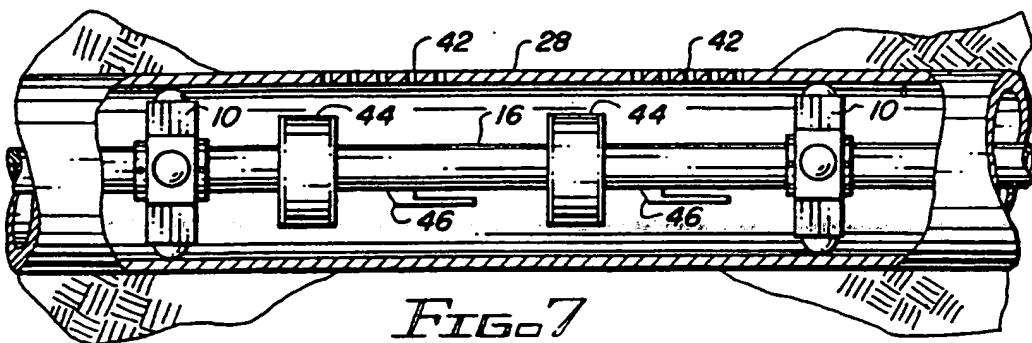


FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PC1/US 94/02974

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 E21B17/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| X | US,A,1 699 087 (WOODMANSEE ET AL.) 15 January 1929 see the whole document | 1,6,7, 9-11 |
| Y | --- | 2-5 |
| Y | US,A,4 995 456 (CORNETTE ET AL.) 26 February 1991 see column 3, line 64 - column 5, line 57; figure 1 | 2,3,5 |
| A | --- | 1,9 |
| Y | US,A,4 811 792 (LEMBCKE ET AL.) 14 March 1989 see abstract; figures | 4 |
| A | --- | 1-3,9 |
| | --- -/-- | |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

3 August 1994

Date of mailing of the international search report

08.08.94

Name and mailing address of the ISA

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Lingua, D

INTERNATIONAL SEARCH REPORT

International Application No
PC1/US 94/02974

| C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|--|---|-----------------------|
| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| X | EP,A,0 333 450 (ANDERSON) 20 September 1989 see column 1, line 55 - column 4, line 6; figures --- | 1,6, 8-10,12 |
| A | US,A,1 517 027 (SMITH) 25 November 1924 see the whole document --- | 1,6,7, 9-12 |
| A | US,A,1 801 294 (SUTTON) 21 April 1931 see the whole document --- | 1,6,7, 9-11 |
| A | US,A,5 040 619 (JORDAN ET AL.) 20 August 1991 see abstract; figures --- | 1-4,9 |
| A | GB,A,2 231 358 (PETROLEO BRASILEIRO SA) 14 November 1990 see page 1, line 1 - page 2, line 24; figures ----- | 1,5,9 |

Form PCT ISA 210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 94/ 02974

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 13
~~because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).~~
See PCT Rule 6.2(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 94/02974

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------------|----------------------|
| US-A-1699087 | | NONE | |
| US-A-4995456 | 26-02-91 | NONE | |
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| US-A-1517027 | | NONE | |
| US-A-1801294 | | NONE | |
| US-A-5040619 | 20-08-91 | EP-A- 0452126 US-A- 5211714 | 16-10-91 18-05-93 |
| GB-A-2231358 | 14-11-90 | NONE | |